O 22: Methods: Scanning probe techniques III

Time: Tuesday 10:30–12:45 Location: H32

O 22.1 Tue 10:30 H32

Scanning Probe Microscopy with a Hydrogen atom — •Jay Weymouth, Thorsten Wutscher, and Franz Giessibl — Institute for Experimental and Applied Physics, Universität Regensburg, D-93040 Regensburg, Germany

Scanning probe microscopy requires atomically sharp tips in order to image surfaces with atomic resolution. One way to increase the spatial resolution of a single-atom tip is to use a lighter atom as the front atom. While tungsten, with a covalent radius of 130 pm, is common as a tip material for SPM, it has been shown that carbon, with a covalent radius of 77 pm, can be used to probe the orbitals of a tungsten atom [Hembacher et al., Science (2004)]. Carrying on, hydrogen has the smallest covalent radius and is thus an ideal candidate for the front atom. Hydrogen has the additional benefit of passivating the tip and thus strongly decreasing reactivity, which may be beneficial for SPM tips operating in the repulsive force regime. We report on our work creating and characterizing hydrogen-terminated silicon tips.

O 22.2 Tue 10:45 H32

Imaging surfaces with scanning tunneling hydrogen microscopy — •Christian Weiss[1,2], Stefan Tautz[1,2], and Ruslan Temirov[1,2] — [1]Institut für Bio- und Nanosysteme (IBN-3) and — [2]JARA Fundamentals of Future Information Technology

Recently it has been demonstrated that a single hydrogen molecule confined in the junction of a scanning tunneling microscope (STM) acts as a combined force-sensor/signal transducer that probes the local surface adsorption potential and converts the force signal into variations of the junction conductance [1]. Images taken with the new method, called scanning tunnelling hydrogen microscopy (STHM), show an ultra-high geometric resolution, which resembles chemical structure formulae of the imaged compounds [2]. In our contribution we discuss applications of the STHM to imaging of various surfaces and show the operation in two different regimes. In one regime the hydrogen sensor maps the repulsive short-range interactions [1], while in the other possibly the attractive ones.
References:
[1] C. Weiss et al. arXiv:condmat/0910.5825
[2] R. Temirov et al. 2008 New. J. Phys 10 053012

O 22.3 Tue 11:00 H32

An atomic force microscope scanner for high speed, large range and high resolution imaging — •Christoph Braunsmann and Tilman Schäffer — Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Staudtstr. 7, Bau A3, 91058 Erlangen

We constructed a high-speed AFM for imaging large areas at high resolution. This involved significantly increasing the bandwidth of every single AFM component. Besides the electronics, the data acquisition system and the cantilever, one important such component is the scanner. By using finite element modeling we developed a fast three-dimensional scanner based on piezo stacks and flexures. The scanner design is modular and allows for an easy exchange of the x- and y-piezos. Large x- and y-piezos achieve scan sizes of up to 23 μm × 23 μm, which is the largest scan size for a feedback-controlled xyz high-speed scanner reported to-date. Smaller x- and y-piezos can be employed giving high lateral resolution. We demonstrated the high speed performance of the new scanner by imaging collagen fibrils in air (14 images/s) and calcite dissolution in hydrochloric acid (10 images/s) with small cantilevers (18 μm in length). Tip-sample velocities of up to 8.8 mm/s and z-piezo velocities of up to 11 mm/s were reached while scanning. By resolving the hexagonal lattice of the (001) cleavage plane of muscovite mica with a small cantilever in water we showed that the scanner is not only suited for high-speed imaging at large range, but can also give resolution on the atomic scale.

O 22.4 Tue 11:15 H32

AFM with Light-Atom Tip — •Thomas Hofmann, Joachim Welker, and Franz J. Giessibl — University of Regensburg, Faculty of Experimental and Applied Physics II - Physics, Universitätsstrasse 31, D-93053 Regensburg

STM and AFM images are a convolution of the tip and the sample wave functions. Hence, for maximal resolution, the size of the protruding tip orbital has to be minimized. Beryllium is a promising candidate as tip material because a Beryllium atom has just four electrons, leading to a covalent radius of only 89 pm. In addition to being conductive, it has a high binding energy, which is a necessity for a stable tip cluster. For imaging with Beryllium tips a new tip preparation method was developed: High voltage is applied to the tip and the tip is crashed into a metal plate, resulting in a clean, oxide-free surface. After the preparation, dynamic STM images of the Si-(111)-(7×7) surface can be obtained and compared with images recorded with a Silicon tip. To specify the resolution of the images, the apparent radii of curvature of the imaged atoms are determined. With a Beryllium tip atom a radius of curvature of minimal 4.0 Å can be achieved. In comparison, a tip terminated by a Silicon atom only provides a radius of 8 Å. Furthermore, FM-AFM images with atomic resolution can be obtained with Beryllium tips. These images indicate even smaller radii of curvature (2.6 Å) than the STM images.

O 22.5 Tue 11:30 H32

Simulations of metastable states near the apex of a KBr tip — •Regina Hoffmann[1] and Alexis Baratoff[2] — [1]Physikalisches Institut, Karlsruhe Institute of Technology — [2]Institut für Physik, Universität Basel

Telegraph-like noise in the low-temperature resistance of small conductors has been explained by a single defect hopping between two energy minima separated by a barrier. A similar phenomenon correlated with additional energy dissipation has been observed in dynamic AFM near contact to a KBr(001) sample [1]. The authors attributed this behaviour to a KBr molecule hopping near the apex of the tip, rather than between tip and sample. We report results of atomistic simulations for such a system using a code validated in studies of AFM on ionic crystals [2]. The simulated system consists of a 4*4*4 cube supplemented by one additional K ion bound to a nearby Br ion. Relaxation led to the first stable configuration A. Another stable configuration was found by flipping one of the Br coordinates (x) by about one lattice constant; subsequent relaxation led to the more stable position E. In order to map the potential energy landscape between positions A to E, we incremented the Br x-coordinate forward and backward while relaxing its other coordinates and those of the other ions. Simulations in the presence of a KBr(001) sample indicate that the molecule stays near the tip apex and that additional states with lower energy barriers occur. This may account for the observed jumps. [1] R. Hoffmann et al., Nanotechnology 18, 395503 (2007). [2] T. Trevethan and L. Kantorovich, Nanotechnology 15, S34 (2004)

O 22.6 Tue 11:45 H32

Advances in Quantitative Nanomechanical Mapping, and robust, user-friendly AFM tapping — •Johannes Kindt[1], Chanmin Su[2], Shuiqing Hu[2], and Bede Pittenger[2] — [1]Veeco GmbH, Dynamostr. 19, 68165 Mannheim — [2]Veeco Metrology, 112 Robin Hill Road, Santa Barbara, CA 93117

The AFM has long been recognized for its ability to resolve surfaces at nm-resolution, and to probe mechanical properties and interactions on the sample surface by local mechanical measurement. However, until recently, the combination of these two capabilities was often a compromise between achievable imaging rate, and amount of property data collected - Examples are force volume maps collected over hours, or AFM images with a few select measurement points for mechanical properties. Here, we present recent advances in AFM technology that allow the collection of mechanical data (modulus, adhesion, deformation, dissipation) at normal AFM imaging rates. We also present an implementation of this technology that greatly simplifies AFM tapping operation while at the same time making it more robust, and the interaction more controlled.

O 22.7 Tue 12:00 H32

Magnetic Force Microscopy with a qPlus Sensor — •Maximilian Schneiderbauer and Franz J. Giessibl — Institute for Experimental and Applied Physics, Universität Regensburg, Universitätsstrasse 31, 93053 Regensburg, Germany

Magnetic Force Microscopy (MFM) plays an important role in investigating magnetic storage materials. Until now experiments were mainly performed with standard silicon cantilevers whose tips have been coated with ferromagnetic materials. Such cantilevers have a resonance frequency on the order of 200 kHz and spring constant k of about 20 N/m. This enables spatial resolution of approximately 15 nm. To prevent snap to contact from strong magneto static forces at closest separation one needs a much stiffer cantilever. The qPlus sensor with k approximately 2000 N/m is therefore a promising candidate for MFM measurements. In this talk preliminary results achieved with a qPlus based force sensor are presented.

O 22.8 Tue 12:15 H32

Observing a qPlus sensor oscillate

— Joachim Welker, •Alfred J. Weymouth, and Franz J. Giessibl — Institute for Expermental and Applied Physics, University of Regensburg, Germany

The qPlus sensor [1] has been widely used in FM AFM for investigations of various surfaces. The qPlus sensor consists of a quartz tuning fork with one prong fixed to a massive substrate, so that the motion is can be described as harmonic oscillator. Real time observation of the oscillations of a qPlus sensor would require a high-speed video recorder with a framerate on the order of 50 kHz. However, by using a stroboscopic light with frequency $f_{\text{light}} = f_{\text{qPlus}} \pm \Delta f$, the oscillation of the sensor can be recorded at the beat frequency Δf with a much lower frame rate. This allows us to explore the single harmonic oscillation motion that is used to model the movement of the tip. In the new three-contact design of the qPlus sensor, a gold wire is used to bias the tip for STM operations. This measurement also provides information about the role of the gold wire on tip oscillations.

[1] F. J. Giessibl, et al., Nanotechnology 15, S79-S86 (2004)

O 22.9 Tue 12:30 H32

Dynamic Force Microscopy with Small Amplitudes at Ambient Conditions

— •Elisabeth Köstner and Franz J. Giessibl — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg

Yamada et al. [1,2] have shown that it is possible to obtain atomic resolution on cleaved mica and calcite in water with frequency-modulation force microscopy. These impressive results were acquired with a setup that enabled them to get very low deflection noise density, which is decisive for atomic resolution.

We have approached the problem of ambient condition imaging with quartz tuning fork based (qPlus) cantilevers. We tried to simplify our setup by using very stiff cantilevers (spring constant of 4300 N/m) with small amplitudes (around one nanometer). However, independent of the cantilever, small amplitudes appear to be necessary for high resolution imaging. Results made in frequency-modulation force microscopy mode with this setup are presented showing monoatomic steps on silicon in air and on calcite in PEG (polyethylenglycol).

[1] T. Fukuma, K. Kobayashi, K. Matsushige, and H. Yamada, Appl. Phys. Lett. 87, 034101 (2005)

[2] S. Rode, N. Oyabu, K. Kobayashi, H. Yamada and A. Kühnle, Langmuir 25, 2850-2853 (2009)